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IS 10911 (1984): Methods of inspection for straight bevel gears [PGD 31: Bolts, Nuts and Fasteners Accessories]

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Indian Standard

METHODS OF INSPECTION FOR STRAIGHT BEVEL GEARS

1. Scope — *Covers the methods of inspection for straight bevel gears.*

2. Terminology — For the purpose of this standard, the definitions and nomenclature given in IS : 2458 (Part 2) - 1984 'Glossary of terms for bevel and hypoid gears' are applicable.

3. Inspection Methods — Covers the following broad areas:

  a) Gear blank inspection,

  b) Gear inspection, and

  c) Gear assembly inspection.

  Information on tolerances for bevel and hypoid gear blanks are given in Appendix A.

3.1 *Gear Blank Inspection* — The inspection methods and the type of tooling used are generally determined by the size of the blank, the shape of the blank, the quantities involved and the quality level required. Figure 1 is a typical bevel gear drawing showing all the gear blank dimensions.
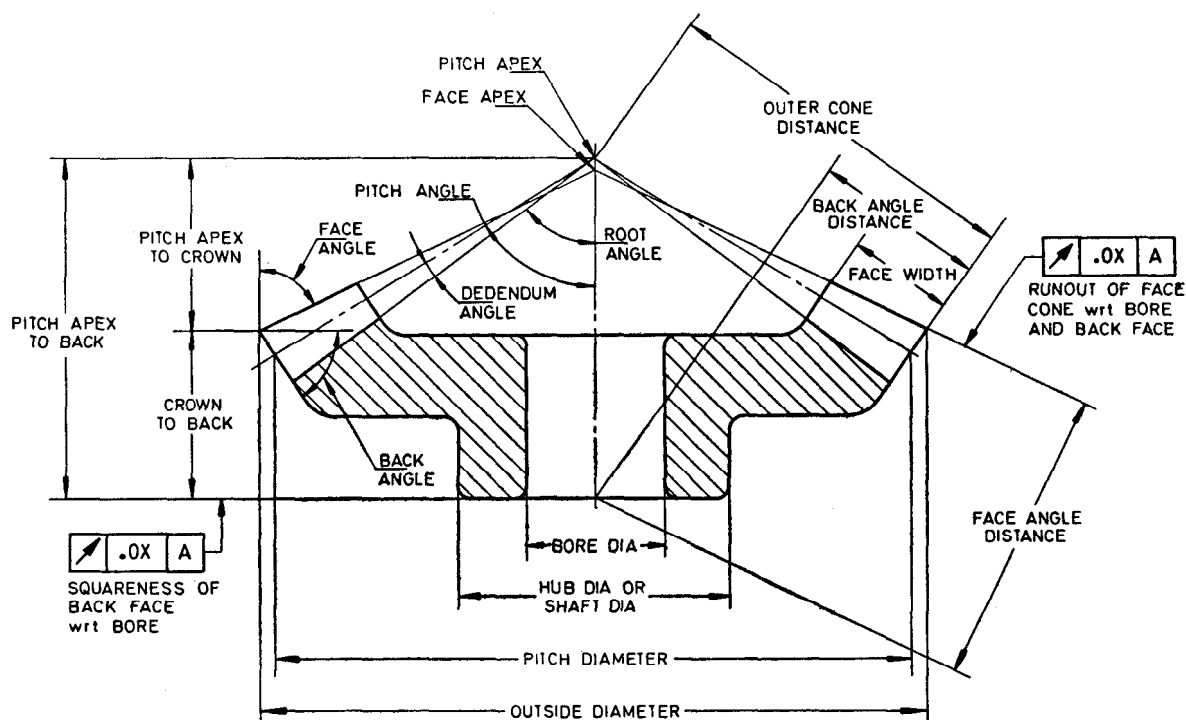

FIG. 1 TYPICAL STRAIGHT BEVEL GEAR BLANK DRAWING

3.1.1 Dimensions connected with bores, external diameters, lengths and concentricity shall be inspected with standard measuring instruments or simple gauges.

3.1.2 The following parameters shall be inspected which call for special methods and devices:

    a) Crown to back dimension,

    b) Face cone position,

    c) Outside diameter,

    d) Face angle,

    e) Back angle, and

    f) Runout of gear blank with respect to locating surfaces.

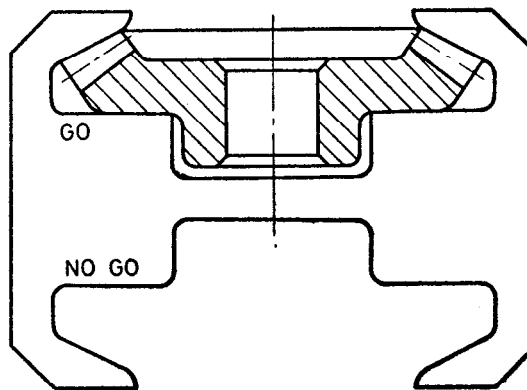**3.1.3** Figure 2 shows a typical profile gauge to check face angle, crown to back dimension and face cone position.

FIG. 2 TYPICAL PROFILE GAUGE FOR CHECKING FACE ANGLE,
CROWN TO BACK DIMENSION AND FACE CONE POSITION

3.1.4 Figure 3 shows a typical profile gauge for checking back angle.
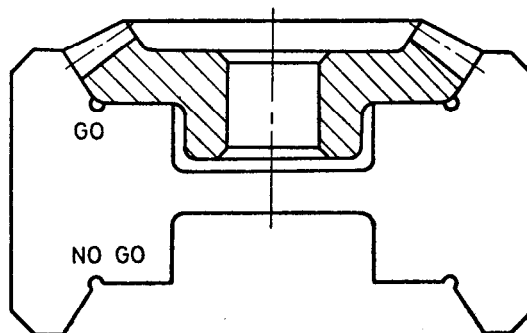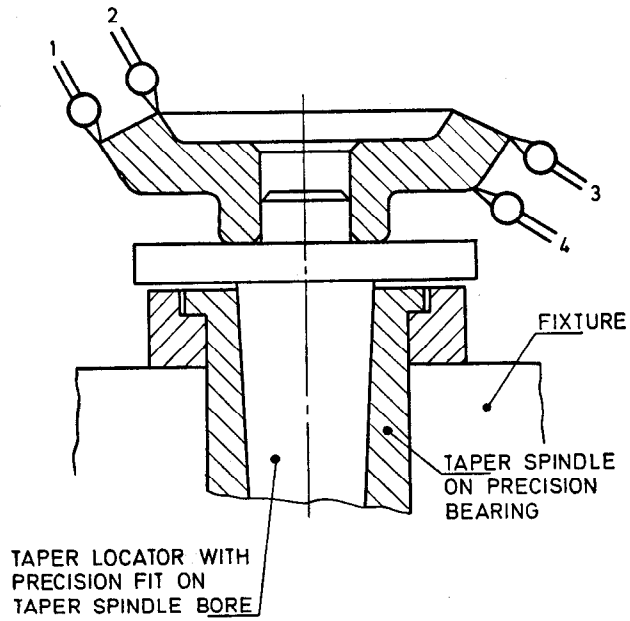
FIG. 3 TYPICAL PROFILE GAUGE FOR CHECKING BACK ANGLE

3.1.5 Figure 4 shows simple bench fixture arrangement used with a master blank to set the dial probes. This arrangement shall check:
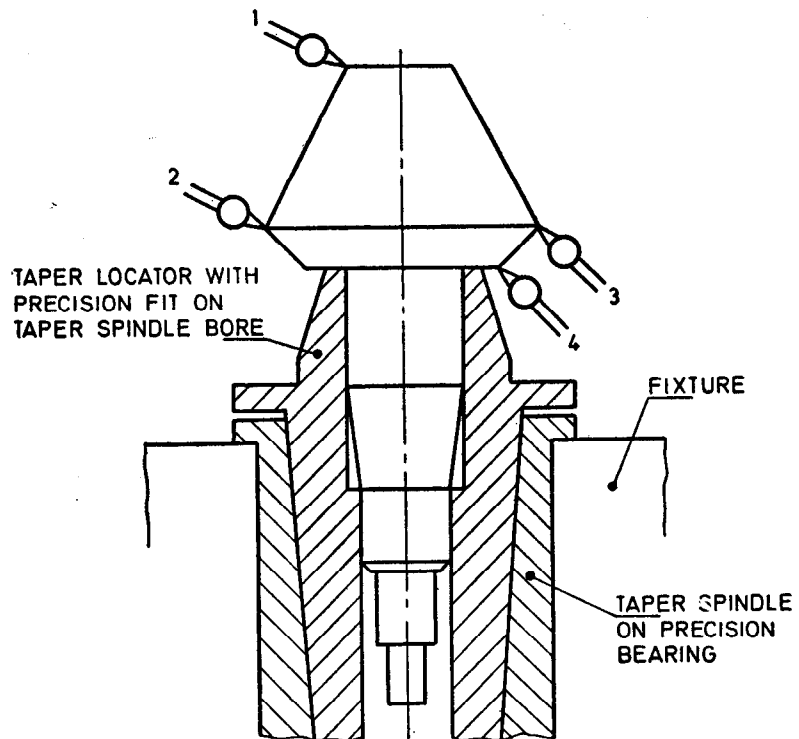
    a) Crown to back dimension,

    b) Outside diameter,

    c) Face angle and face cone position,

    d) Back angle and back cone position, and

    e) Runout of face cone and back cone with respect to the locating surfaces.

2

Note — Dials 1, 2, 3 and 4 are to be set with Master Gear First.

FIXTURE

TAPER SPINDLE ON PRECISION BEARING

TAPER LOCATOR WITH PRECISION FIT ON TAPER SPINDLE BORE

Dials 1 and 2 Check Position of Face Cone
Dials 3 and 4 Check Position of Back Cone

Note — Dials 1, 2, 3 and 4 are to be set with Master Gear First.

TAPER LOCATOR WITH PRECISION FIT ON TAPER SPINDLE BORE

FIXTURE

TAPER SPINDLE ON PRECISION BEARING

Dials 1 and 2 Check Position of Face Cone
Dials 3 and 4 Check Position of Back Cone

FIG. 4 FIXTURES FOR CHECKING POSITION OF FACE AND BACK CONES

3

3.1.6 A universal Blank checker for inspecting bevel gear blanks from 50 mm to 500 mm is shown in Fig. 5 for checking face angle, back angle, outside diameter, crown to back dimension, face cone position and back cone position. Since all settings of dials are made by gauge blocks and verniers, no master blanks are necessary. Figure 6 shows the systems of inspection tolerances for bevel gears.

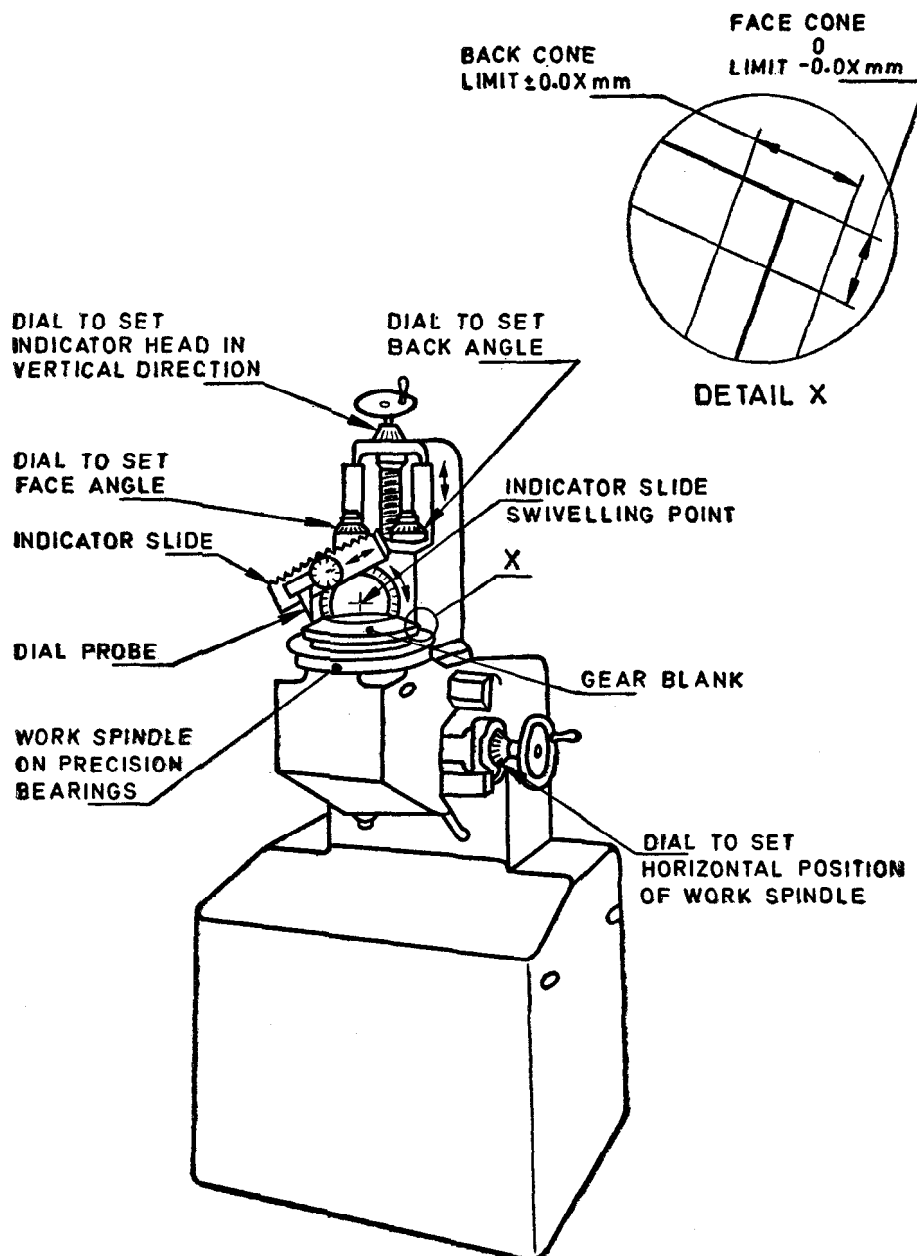Note — Both the above systems are in use depending on inspection facility available.

FIG. 5 BEVEL GEAR BLANK INSPECTION MACHINE

3.1.7 Very large bevel gear blanks are inspected by measuring instruments like bevel protractor for angle checking and height gauges for crown to back dimensions (see Fig. 7).

3.1.8 Blanks for small precision bevel gears are inspected by optical projection on a comparator.
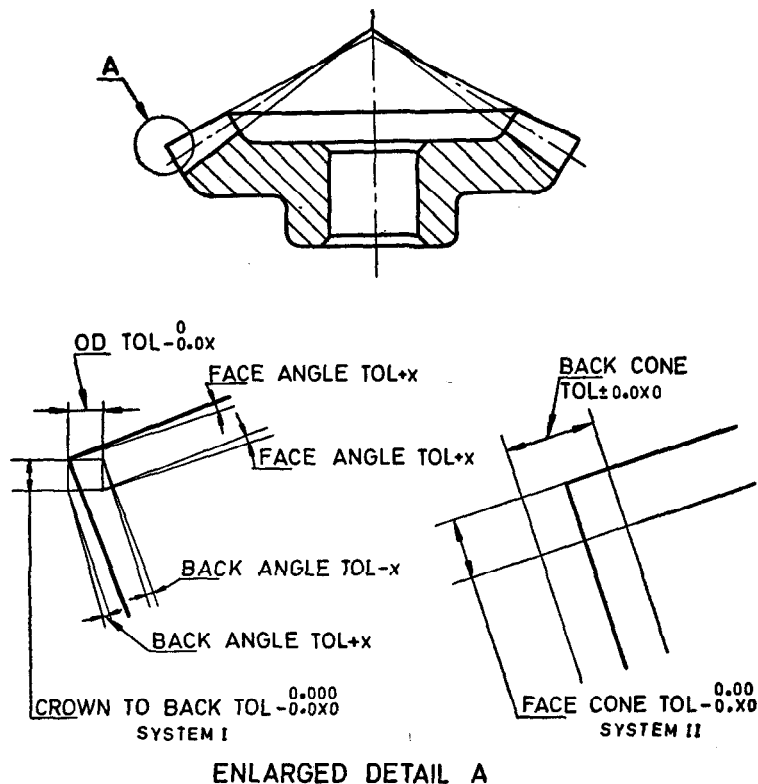
ENLARGED DETAIL A

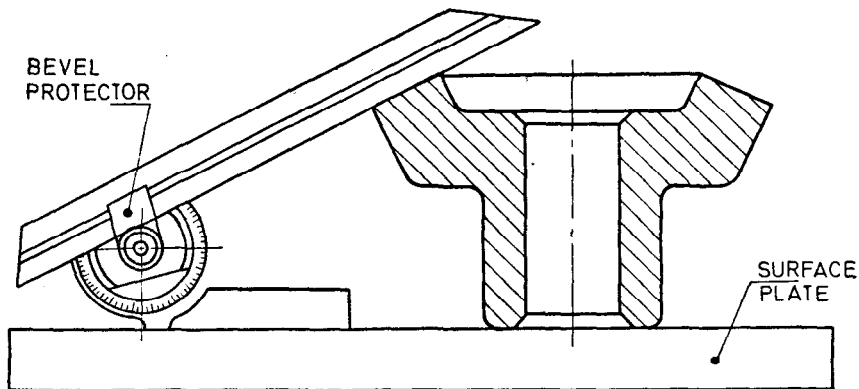FIG. 6 SYSTEMS OF INSPECTION TOLERANCES FOR BEVEL GEARS

FIG. 7 FACE ANGLE CHECK WITH BEVEL PROTRACTOR

3.1.9 *Proof spots* — On certain gear blanks proof spots are provided which are accurately machined surfaces with minimum axial and radial runout, with respect to locating surfaces. The purpose of providing proof spots is :

a) On shank type gears, the proof spots are used to inspect the runout of shank with respect to the gear pitch circle diameter while straightening after heat treatment. This indirectly controls the runout of pitch circle diameter of gear with respect to centres used for grinding the locating surfaces after heat treatment (*see* Fig. 8).

b) When assembly locating surfaces are delicate for gear cutting operation, proof spots act as auxiliary locating surfaces. All inspection can be carried out with respect to these auxiliary locating surfaces (*see* Fig. 9).

c) Proof spots act as reference surfaces for truing the pitch circle gear in the absence of pitch line chucks for hard grinding of locating surfaces after heat treatment (*see* Fig. 10).

d) Proof spots are also used for checking trueness of gears in assembly.
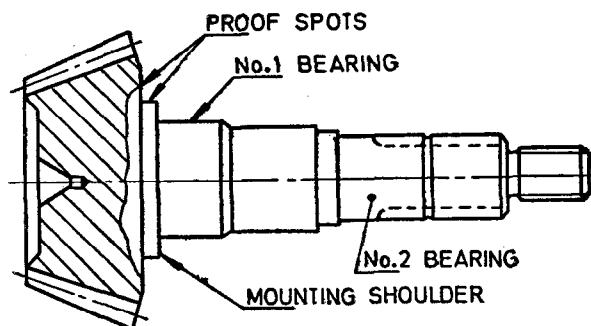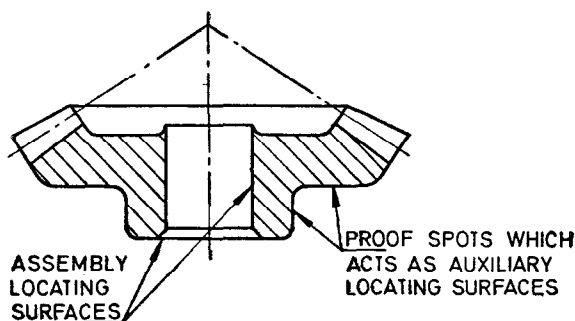
5

FIG. 8 SHANK TYPE PINION

FIG. 9 INSTRUMENT GEAR WITH DELICATE CONSTRUCTION FOR GEAR CUTTING
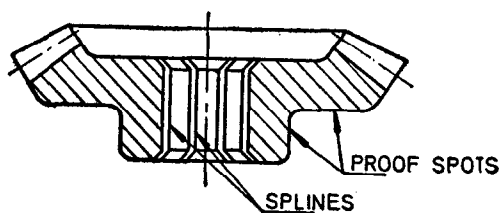
FIG. 10 GEAR WITH SPLINED BORE

3.2 *Straight Bevel Gear Inspection* — The inspection of straight bevel gears calls for a different approach from those of spur gears as :

a) The shape of a straight bevel gear tooth varies from end to end; as such measuring involute tooth profile is a difficult proposition.

b) The most conclusive test of straight bevel gears is their satisfactory operation under normal running conditions in their final mountings.

Testing machines are designed to provide a running test of straight bevel gears simulating the normal running conditions in their final mountings as also to facilitate assessment of the characteristics of tooth contact for its suitability or corrective action.

3.2.1 *Inspection equipment for straight bevel gears and their description*

3.2.1.1 *Bevel gear testing machines* — The testing machine is the most versatile inspection equipment to assess the ultimate quality standards of a bevel gear set for most of the applications. The running test checks the gears of the following conditions:

a) Actual mounting distance of gear and pinion with reference to theoretical specifications of mounting distance;

b) Tooth size in relation to a master mating gear or pinion or with reference to the mating gear or pinion;

c) The position and shape of tooth contact;

d) The quality of surface finish;

e) The amount of root clearance;

*f) Visual concentricity as seen by contact variation;

*g) Double flank roll test;

h) Interference;

i) General running qualities of the gear set, and

j) Vertical and horizontal movement tolerances of the gear sets with respect to specified mounting distance—This will be a composite check for the suitability of contact parameters.

3.2.1.2 *Types of testing machines* — Primarily there are two types of testing machines :

a) The Right Angle Testing machines for gears operating at 90° shaft angle (*see* Fig. 11).
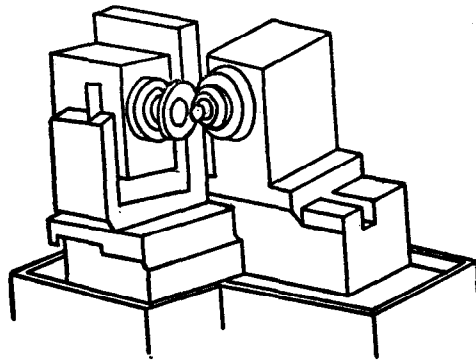

FIG. 11 RIGHT ANGLE TESTING MACHINE

b) The Universal Testing Machines for gears operating at any shaft angle (*see* Fig. 12).
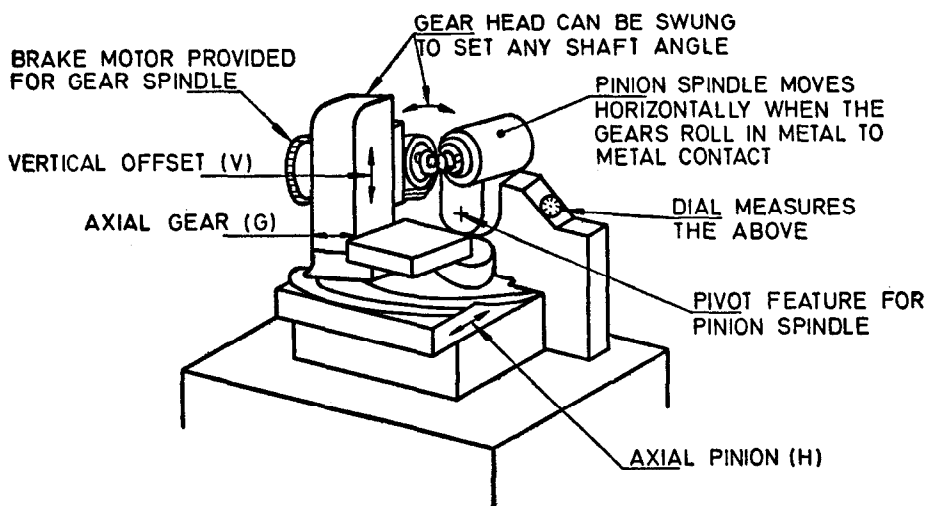

FIG. 12 UNIVERSAL GEAR TESTING MACHINE

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*Spacing errors and concentricity errors are, however, measured in much the same manner as on spur gear when it is necessary to determine the exact values.

3.2.1.3 *Description of testing machines* — Testing machines are designed for positioning the gear and pinion heads by :

a) Axial adjustment of both gear and pinion heads.

b) Vertical offset adjustment of either member.

c) Angular adjustments of gear head with reference to pinion axis (on Universal Testing Machines).

d) Certain testing machines are provided with pivot—construction of pinion head. With this feature the pinion spindle is permitted to move horizontally 0'25 mm either side of centre, but is forced by a light spring pressure in a direction to throw the gears into metal to metal contact when the gears roll in tight mesh (Double flank roll test). The horizontal movement of pinion head due to irregularities is measured by an indicator.

e) Pinion head can be run with a range of speeds, the driven or gear heads being equipped with a brake for applying loads as the gears are run together.

Note — The above adjustments are invaluable when developing the gear tooth contact during cutting, since it is possible to determine the amount and direction of changes necessary in the cutting machine to produce the required tooth contact (*see* Fig. 13). These adjustments are also useful in determining the amount of errors in gear housings. The tooth bearing observed in the housing can be duplicated on the testing machine by varying the testing machine settings from its correct position, which will give a measure of the errors of the housing.
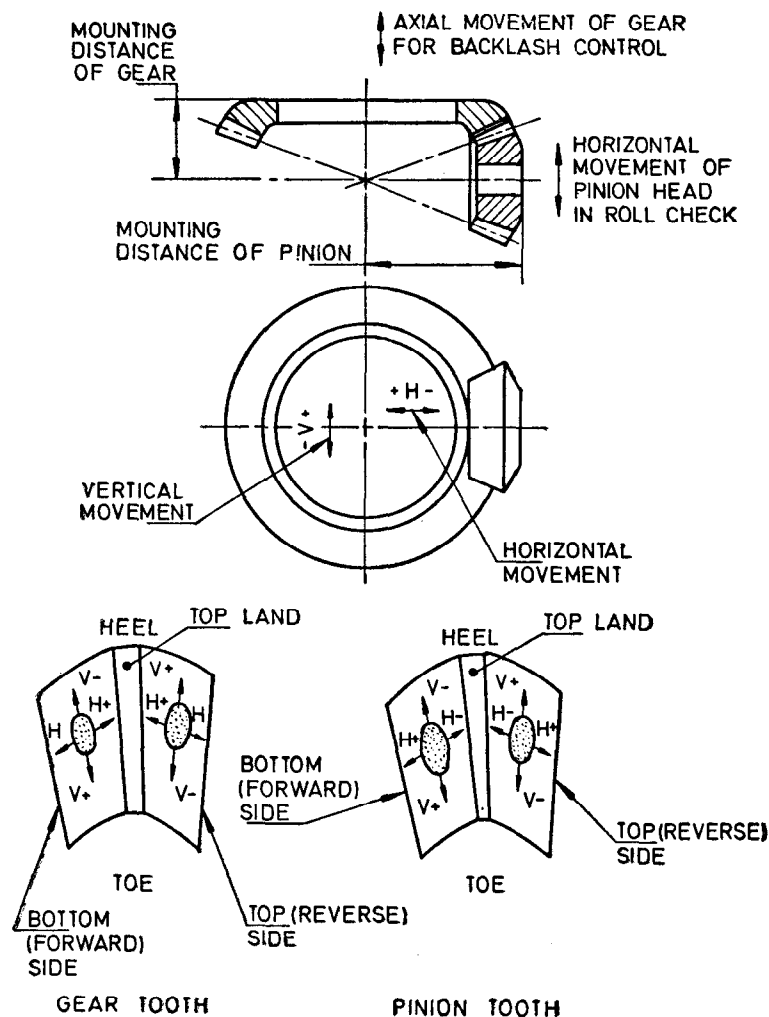

FIG. 13 EFFECT OF CHANGES IN RELATIVE POSITION OF PINION HEAD WITH RESPECT TO GEAR HEAD ON TESTING MACHINE IN THE POSITION OF CONTACTS ON GEAR AND PINION TEETH

3.3 *Inspection Procedure of Straight Bevel Gears* — To accomplish a correct tooth bearing development the following inspection steps shall be adhered to.

3.3.1 The tooth depth of gear and pinion shall be checked against the calculated value by one of the following methods :

a) Tooth depth can be measured by a depth micrometer with a pointed stem. Reading should be taken at the extreme heel end.

b) A root angle master can be used to set the root line position with a single probe dial. Check the root line of cut gear to measure the tooth depth.

c) Gear blank checker can be used to check the root line and hence tooth depth.

Note — Unless smooth bottoms are required straight bevel gears of 2'5 module and coarser are rough cut 0'12 mm to 0'13 mm deeper than the calculated tooth depth.

3.3.2 The chordal tooth thickness of gear and pinion shall be checked against the calculated values by one of the following methods :

a) On medium and coarse pitch gears, the measurement of chordal tooth thickness is usually made with a gear tooth vernier. Having set the vernier for the chordal addendum and chordal thickness the vernier is drawn from the toe end towards the heel end of tooth. If the tooth size is correct, the caliper should touch the top land and sides at the heel end.

Note — Always compensate for dimensional variations of face cone while setting the chordal addendum on the calipers.

b) Tooth thickness is indirectly but accurately controlled by measurements of backlash in production testing.

c) Tooth thickness uniformity in production testing is checked by measuring back face height with reference to pitch cone, by resting cut gear on pins located on a pitch circle in a fixture. One master control gear is used for setting the dial for back face height.

d) Tooth thickness can be accurately controlled by using suitable ball probe, to set the dial on master control gear slot and checking the production gear with the set up.

3.3.3 *Measurement of backlash* — With the gear and pinion on their centres, and the pinion held firmly against rotation, a dial indicator is used with its probe maintained perpendicular to the gear tooth surface at the heel. Backlash reading is taken by rocking the gear back and forth (*see* Fig. 14). Backlash is also measured in production testing, by measuring the axial movement of gear from its centre to metal to metal contact with pinion teeth—slot (this pinion is the control pinion). The reading thus obtained will be proportional to the backlash.

Note — Backlash measurement are taken at the tightest point of mesh with the gears on correct centres and the backlash readings are for normal backlash.

3.3.4 *Inspection Procedure for Development and Production*

3.3.4.1 The work heads on the testing machine should be carefully set so that the gears, when mounted, will be located at their specified mounting distances and specified shaft angle.

Note — The vertical offset should be set on zero, for straight bevel gears.

3.3.4.2 The gear is cut first, as per the calculated settings. It is mounted on the gear head arbor after inspecting for tooth depth and tooth thickness. Then the pinion is cut on calculated settings. After inspecting the pinion for tooth depth, it is mounted on pinion work head for roll testing. Both the gear and pinion are brought on centres and backlash is inspected at the point of tight mesh. If necessary, the pinion is recut to achieve the backlash as required at the point of tight mesh. Also backlash variation is checked by locating the points of maximum and minimum backlash for the gear set.

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Once the above are found to be within desired tolerance the gears are applied with marking compound and run on power, applying a light brake on gear head spindle. Contact position, area of contact and variation, if any, are observed for one full rotation of gear.

Any change required to position the contact has to be carried out on pinion cutting set-up. After the desired contact pattern is achieved, backlash is checked and corrected by recutting, if necessary.
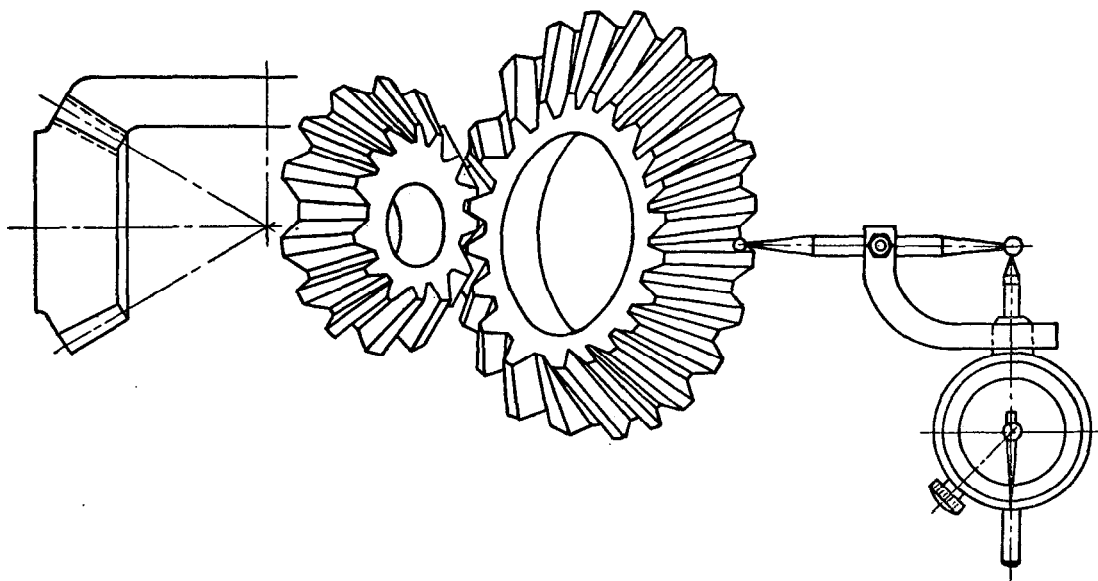
FIG. 14 CHECKING OF NORMAL BACKLASH

3.3.4.3 *Production control gears* — Once cutting machine settings are finalised for gear and pinion, three sets of unhardened control gears and pinions are selected. Out of these three sets of control gears, one set is utilised as 'Master Control Gears' used for checking 'Inspection Control Gears' only, which is the second set. The 'Inspection Control Gears' are used for checking 'The Green Production Control Gears' which is the third set. 'The Green Production Control Gears' are used for checking gears in green or unhardened state.

Note 1 — In the manufacture of control gears, compensation shall be made for the effects of final mounting and for the changes during hardening on production gears by actual trial.

Note 2 — Since they are unhardened, they require to be replaced by new control gears periodically.

Note 3 — For gears which are hardened and ground on teeth a fourth set of 'Preground Production Control Gears, are maintained. These are used for checking gears after they are hardened but before the teeth are ground. These gears are made thin by the amount of grinding stock of the mating production gears.

3.3.4.4 After grinding of locating surfaces with respect to teeth, the pitch circle diameter runouts are checked with respect to these locating surfaces.

3.3.4.5 After grinding of locating surfaces, every gear and pinion is tested on testing machine for backlash and slight changes in mounting distances. On precision gears and in certain applications, backlash and change in mounting distances are etched to facilitate proper selection of spacers of shims for assembly.

3.3.4.6 On high precision work extremely close tolerances of tooth spacing and concentricity must be held. Since checking of these values by sight and sound is not sufficient, they are inspected by direct measurements for tooth spacing and concentricity on tooth spacing tester and concentricity tester (*see* Fig. 15 and 16).
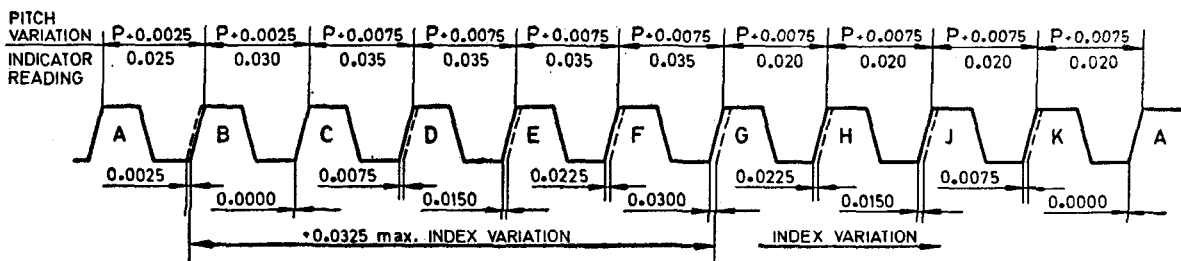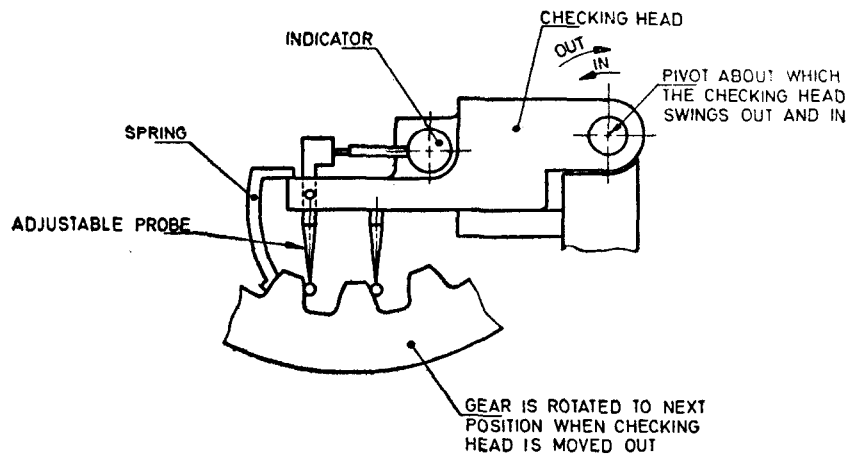
Teeth	Indicator Reading *1	Spacing Variation *2	Pitch Variation *3	Index Variation *4	
A – B	0·025	0·005	– 0·002 5	– 0·002 5	– 0·002 5
B – C	0·030	0·005	+ 0·002 5	0·000 0	
C – D	0·035	0·000	+ 0·007 5	+ 0·007 5	
D – E	0·035	0·000	+ 0·007 5	+ 0·015 0	
E – F	0·035	0·000	+ 0·007 5	+ 0·022 5	
F – G	0·035	0·015	+ 0·007 5	+ 0·030 0	(–) + 0·03
G – H	0·020	0·000	– 0·007 5	+ 0·022 5	0·032 5
H – J	0·020	0·000	– 0·007 5	+ 0·015 0	*Max Index Variation*
J – K	0·020	0·000	– 0·007 5	+ 0·007 5	
K – A	0·020	0·005	– 0·007 5	0·000 0	

1. Set indicator to .025 on first pair of teeth (*1)

2. Record successive indicator readings (*1)

3. Spacing variation (*2) difference of successive readings (*1).

4. Pitch = $\dfrac{\text{(Sum of indicator readings)}}{\text{No. of teeth}}$

5. Pitch variation (*3) is the difference of indicator readings with respect to pitch.

6. Index variation (*4) addition of successive pitch variation (*3)

7. Maximum Index Variation Alg. Subtraction of *Max* and *Min* Values in (*4)

FIG. 15 SCHEMATIC ARRANGEMENT OF TOOTH SPACING TESTER

11

FIXED
PROBE

CENTRE OF BORE

INDICATOR

FIXED PROBE

A

HIGH POINT

CENTRE OF
TEETH

E

CENTRE OF BORE

INDICATOR

FIXED PROBE

B

HIGH POINT

CENTRE OF
TEETH

2E

E

CENTRE OF BORE

FIXED PROBE

C

CENTRE OF
BORE

2E

E

FIXED PROBE

CENTRE
OF TEETH

HIGH POINT

D
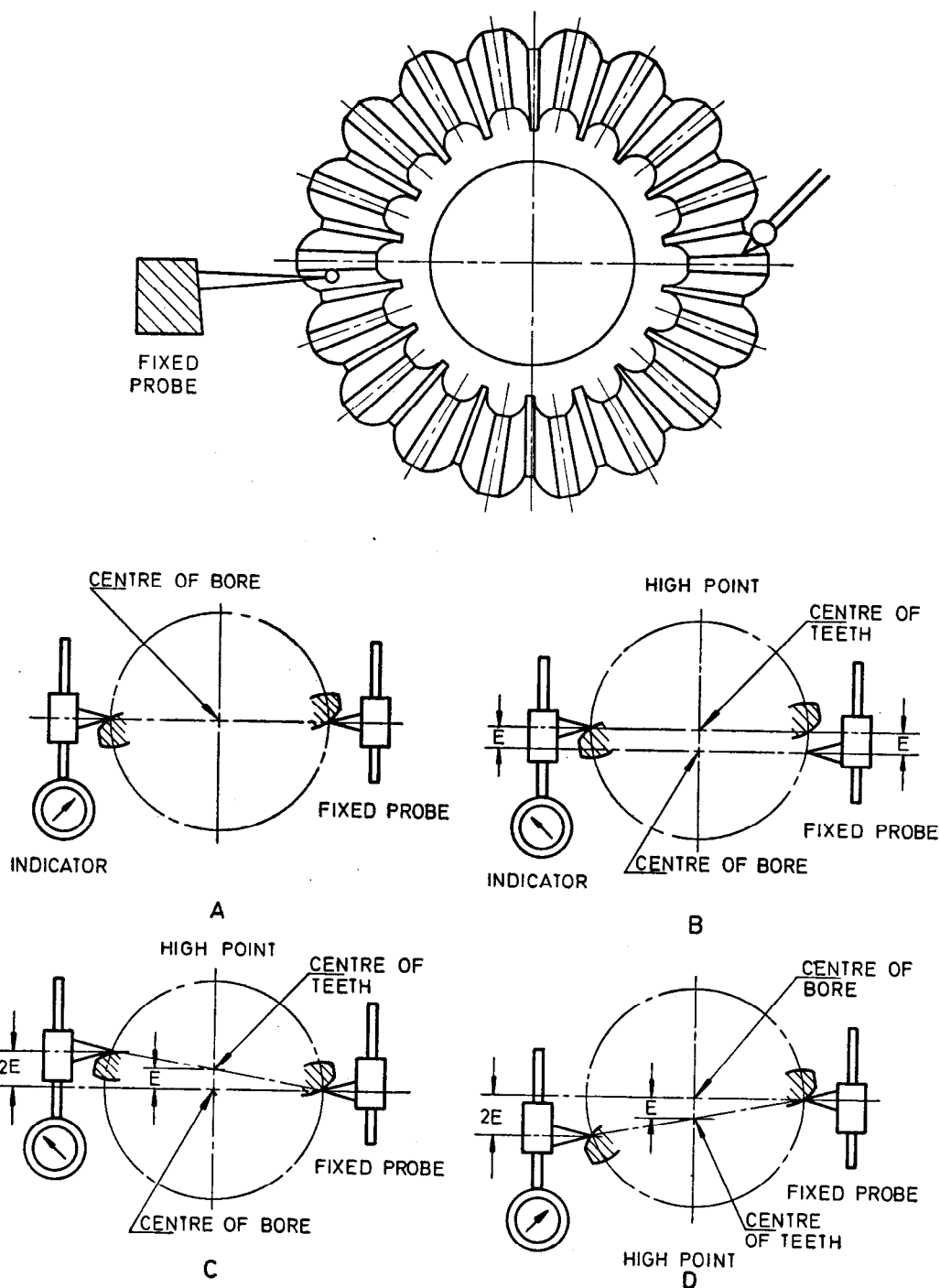
FIG. 16 SCHEMATIC ARRANGEMENT OF CONCENTRICITY TESTER

3.4.4.7 *Inspection after heat-treatment* — Gears after heat-treatment shall be inspected for dimensional distortion on locating surfaces.

4. Straight Bevel Gear Assembly Inspection Procedure

The quality of performance that is designed and manufactured into a set of bevel gears can only be achieved by the correct mounting of the gears at assembly.

4.1 The gear and pinion shall be inspected for any damage, nicks or burrs.

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4.2 The components for sub-assembly and assembly in which the gear and pinion are assembled shall be inspected for cleanliness as well as the dimensions connected with selection of shims or spacers for:

a) Mounting distance corrections.

b) Preloading of bearing on which the gear and pinion rotate,

c) Backlash correction.

4.3 The gear and pinion shall be inspected for any run-out in their mountings (both radial and axial run-out).

4.4 The final assembly shall be inspected for preload of bearings. The assembly shall then be checked for backlash and tooth contact. The assembly shall also be checked for noise while running the drive under light loads. Values of normal backlash at tightest point of mesh for bevel and hypoid gears, are given in Appendix B.

4.4.1 The method of checking normal backlash is shown in Fig. 14.

APPENDIX A

(*Clause* 3)

TOLERANCES FOR BEVEL AND HYPOID GEAR BLANKS

Element of Tolerance	Module, mm		Diameter of Blank Above 40 Up to 800 mm
	Above	Up to	
Crown Circle Diameter Tolerances in μm	— 0·3 0·5 1·25 10	0·3 0·5 1·25 10 —	—50 —75 —100 —125 —250
Crown to Back Dimension Tolerance in μm	— 0·3 0·5 1·25 10	0·3 0·5 1·25 10 —	—25 —25 —50 —75 —100
Face Angle Distance Tolerance in μm	— 0·3 0·5 1·25 10	0·3 0·5 1·25 10 —	—25 —50 —75 —100 —125
Back Angle Distance Tolerance in μm	— 0·3 0·5 1·25 10	0·3 0·5 1·25 10 —	±25 ±25 ±50 ±75 ±125
Face Angle Tolerance in Minutes	— 0·3 0·5 1·25 10	0·3 0·5 1·25 10 —	+40 +30 +15 + 8 + 8
Back Angle Tolerance in Minutes	— 0·3 0·5 1·25 10	0·3 0·5 1·25 10 —	±60 ±60 ±30 ±15 ±15

Note — Applicable to all degrees of accuracy.

Tolerance for Bore or Shaft Diameter

Element of tolerance	Bore or Shaft	Diameter of Bore or Shaft in mm					IS Accuracy Class
		Up to 25	Above 25 Up to 100	Above 100 Up to 250	Above 250 Up to 500	Above 500 —	
Bore or Shaft Diameter tolerance in /μm	Bore	+2·5	+5	+8	—	—	4 and 5
	Shaft	−2·5	−5	−8	—	—	
	Bore	+12·5	+12·5	+25	+25	+50	6 and 7
	Shaft	−12·5	−12·5	−25	−25	−50	
	Bore	+25	+25	+50	+75	+100	8 to 12
	Shaft	−25	−25	−50	−75	−100	

APPENDIX B

(*Clause* 4.4)

VALUES OF NORMAL BACKLASH AT TIGHTEST POINT OF MESH FOR BEVEL AND HYPOID GEARS

Module Above	Module Up to	Values of Normal Backlash in μm			IS Accuracy Class
—	0·32	0	to	18	All Degrees
0·32	0·51	0	to	25	
0·51	1·27	0	to	51	
1·27	1·59	51	to	102	11 and 12
1·59	2·54	76	to	127	
2·54	3·18	102	to	203	
3·18	4·23	127	to	254	
4·23	5·08	152	to	330	
5·08	6·35	203	to	406	
6·35	7·26	254	to	508	
7·26	8·49	305	to	559	
8·49	10·16	381	to	635	
10·16	12·7	508	to	762	
12·7	14·5	508	to	101 6	
14·5	16·92	635	to	114 3	
16·92	20·32	889	to	139 7	
20·32	25·4	1143	to	165 1	
1·27	1·59	25	to	76	4 to 10
1·59	2·54	51	to	102	
2·54	3·18	76	to	127	
3·18	4·23	102	to	152	
4·23	5·08	127	to	178	
5·08	6·35	152	to	203	
6·35	7·26	178	to	229	
7·26	8·49	203	to	280	
8·49	10·16	254	to	330	
10·16	12·7	305	to	406	
12·7	14·5	356	to	457	
14·5	16·92	406	to	559	
16·92	20·32	458	to	661	
20·32	25·4	508	to	762	

EXPLANATORY NOTE

The field of straight bevel gears differs considerably in manufacturing techniques and applications from cylindrical gears. Consequently, the inspection methods also differ considerably. The inspection methods detailed in this standard are already regarded as reliable in the gear industry.

The quality level of a gear is determined during its manufacture by the specific sequence of steps followed and the degree of care employed at each step. The methods by which gear accuracy is achieved and maintained through control of manufacturing planning, machine tool maintenance, fixture maintenance, cutting tool selection and maintenance, heat treatment control and quality assurance programmes as needed, is defined as 'Process Control'. In view of the complexities involved in bevel gear manufacture the concept of ''Process Control'' is formalised in this standard as a quality determinant.

In the preparation of this standard, assistance has been derived from Gleason bevel gear system, AGMA and work done at the International level.